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Invention: FUEL INJECTION PUMP AND ROTATION-LINEAR MOTION TRANSFORMING MECHANISM WITH SAFEGUARD

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FUEL INJECTION PUMP AND ROTATION-LINEAR MOTION TRANSFORMING MECHANISM WITH SAFEGUARD

BACKGROUND OF THE INVENTION

1 Technical Field of the Invention

The present invention relates generally to a fuel injection pump and a rotation-to-linear motion transforming mechanism installed in such a pump which may be employed in delivering fuel to a common rail for diesel engines, and more particularly to a safeguard for such a fuel injection pump and a rotation-to-linear motion transforming mechanism which is responsive to input of an excessive torque to be broken to avoid breakage of the device itself.

2 Background Art

Japanese Patent First Publication No. 2000-240531, assigned to the same assignee as that of this application, discloses a typical one of fuel injection pumps which is equipped with a rotation-to-linear motion transforming mechanism, as illustrated in Fig. 5.

The rotation-to-linear motion transforming mechanism includes an eccentric cam *J2*, a cam ring *J4*, and a plunger *J6*. The eccentric cam *J2* is coupled to a cam shaft *J1* so that it rotates eccentrically with respect to the cam shaft *J1*. The cam ring *J4* is fitted on the periphery of the eccentric cam *J2* through a hollow cylindrical plain bearing (bush) *J3* and urged by the cam ring *J4* to rotate. The plunger *J6* is disposed within a cylinder head *J5* movably in a direction perpendicular to an axis of rotation of the

eccentric cam *J2* and urged by a coil spring into slidable abutment with the cam ring *J4*. Specifically, the plunger *J6* has a flat surface *J8* formed on an end thereof. The cam ring *J4* has formed on the periphery thereof a flat surface *J7* on which the flat surface *J8* of the plunger *J6* abuts slidably, thereby holding the cam ring *J4* from rotating following rotation of the eccentric cam *J2*. This causes the plunger *J6* to reciprocate within the cylinder head *J5* in synchronization with the rotation of the cam shaft *J1*.

The cam ring *J4* is covered with a housing (not shown). A cam chamber is defined between the cam ring *J4* and the housing and filled with fuel which serves to lubricate a contact surface between the cam ring *J4* and the plunger *J6*.

If the water enters between the flat surface *J7* of the cam ring *J4* and the plunger surface *J8* for some reason, it will result in a lack of lubrication therebetween, which may lead to baking of the contact surface between the flat surface *J7* and the plunger surface *J8* which results in a greater thrust resistance. The eccentric cam *J2* is, as described above, driven by the output of the engine. The baking of the contact surface between the flat surface *J7* and the plunger surface *J8*, thus, causes a greater toque outputted from the engine to be transmitted through the contact surface to the plunger *J6*, which may result in breakage of the plunger *J6*. The breakage may further cause fragmentations of the plunger *J6* to be forced into a gap between the cam ring *J4* and the housing (usually made of aluminum) surrounding the cam ring *J4*, which results in breakage of the housing. The avoidance of breakage of the housing requires

an increased clearance between the cam ring *J4* and the housing, but it results in an increase in size of the fuel injection pump.

If the housing is not broken, but the baking of the contact surface between the cam ring *J4* and the plunger *J6* creates a greater resistance to thrust of the plunger *J6*, it will cause a greater torque to act on the plunger *J6* which may result in deformation or fracture of the plunger *J6*, the cylinder head *J5*, and/or the cam ring *J4*.

SUMMARY OF THE INVENTION

It is therefore a principal object of the invention to avoid the disadvantages of the prior art.

It is another object of the invention to provide a rotation-to-linear motion transforming mechanism and a fuel injection pump which are designed to minimize breakage thereof when a contact surface between a cam ring and a plunger creates a greater resistance to the thrust of the plunger.

According to one aspect of the invention, there is provided a rotation-to-linear motion transforming apparatus which comprises: (a) an eccentric cam coupled to a torque input shaft, the eccentric cam being rotated eccentrically with respect to the torque input shaft; (b) a cam ring which is placed in contact of an inner wall thereof with the eccentric cam and to be urged by the eccentric cam to rotate, the cam ring having a flat surface formed on an outer periphery thereof; (c) a plunger placed to be movable linearly in a direction perpendicular to an axis of rotation of the eccentric cam,

the plunger having a flat surface which is pressed against the cam ring in slidable abutment with the flat surface of the cam ring so as to hold the cam ring from rotating to move the plunger linearly; and (d) a safeguard provided in the cam ring which is responsive to application of a physical load greater than a given degree in a direction of rotation of the eccentric cam to undergo breakage. If a contact surface between the cam ring and the plunger is baked to produce a greater resistance to the thrust of the plunger, it will cause the safeguard to be broken to expand the cam ring so that the inner diameter of the cam ring increases. This causes the eccentric cam to idle inside the inner periphery of the cam ring, thereby interrupting transmission of the torque of the eccentric cam to the cam ring to avoid addition of a greater physical load to the plunger. Specifically, when the contact surface between the cam ring and the plunger creates the greater resistance to the thrust of the plunger, the safeguard works to have only the cam ring experience breakage, thus resulting in minimized damage to the rotation-to-linear motion transforming mechanism.

In the preferred mode of the invention, the safeguard is provided in a portion of the cam ring which is out of abutment with the plunger and to which a tensile stress is added when resistance to sliding motion of the cam ring relative to the plunger increases. Specifically, when the contact surface between the cam ring and the plunger creates the greater resistance to thrust of the plunger, a smaller load acting on the cam ring in the direction of rotation thereof results in the breakage of the safeguard.

The safeguard may be implemented by a groove formed in at least one of an outer periphery and an inner periphery of the cam ring. The groove may be of V-shape, U-shape, or C-shape in cross section. The groove may extend from one end to the other end of the cam ring in an axial direction thereof or alternatively be formed only in a portion of the cam ring.

According to the second aspect of the invention, there is provided a fuel injection pump for an engine which comprises: (a) a housing having formed therein a cam chamber into which fuel is supplied; (b) an eccentric cam disposed within the cam chamber of the housing in mechanical connection with a torque input shaft into which torque outputted by an engine is inputted, the eccentric cam being rotated eccentrically with respect to the torque input shaft; (c) a cam ring which is placed in contact of an inner wall thereof with the eccentric cam and to be urged by the eccentric cam to rotate, the cam ring having a flat surface formed on an outer periphery thereof; (d) a plunger placed to be movable linearly in a direction perpendicular to an axis of rotation of the eccentric cam, the plunger having a flat surface which is pressed against the cam ring in slidable abutment with the flat surface of the cam ring so as to hold the cam ring from rotating, thereby urging the plunger to reciprocate to increase and decrease a volume of a fuel pressurizing chamber cyclically; and (e) a safeguard provided in the cam ring which is responsive to application of a physical load greater than a given degree in a direction of rotation of the eccentric cam to undergo breakage. If the water enters between the flat surface of the cam

ring and the flat surface of the plunger for some reason, it will result in a lack of lubrication therebetween, which may lead to baking of a contact surface between the flat surfaces of the cam ring and the plunger which results in a greater resistance to thrust of the plunger. The resistance causes a greater torque outputted from the engine to be added to the cam ring, thereby resulting in breakage of the safeguard. The cam ring, therefore, expands so that the inner diameter thereof increases. This causes the eccentric cam to idle inside the inner periphery of the cam ring, thereby interrupting transmission of the torque of the eccentric cam to the cam ring to avoid addition of a greater physical load to the plunger. Specifically, when the contact surface between the cam ring and the plunger creates the greater resistance to thrust of the plunger, the safeguard works to have only the cam ring experience breakage, thus resulting in minimized damage to the fuel injection pump and avoidance of leakage of fuel from the fuel injection pump. The use of the safeguard eliminates the need for increasing a clearance between the housing and the cam ring, that is, the size of the fuel injection pump.

Only the cam ring is broken, thus minimizing physical damage to the plunger and the cam ring. This results in decreased costs for repair of the fuel injection pump.

In the preferred mode of the invention, the safeguard is provided in a portion of the cam ring which is out of abutment with the plunger and to which a tensile stress is added when resistance to sliding motion of the cam ring relative to the plunger increases.

Specifically, when the contact surface between the cam ring and the plunger creates the greater resistance to thrust of the plunger, a smaller load acting on the cam ring in the direction of rotation thereof results in the breakage of the safeguard.

The safeguard is implemented by a groove formed in at least one of an outer periphery and an inner periphery of the cam ring. The groove may be of V-shape, U-shape, or C-shape in cross section. The groove may extend from one end to the other end of the cam ring in an axial direction thereof or alternatively be formed only in a portion of the cam ring.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given hereinbelow and from the accompanying drawings of the preferred embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments but are for the purpose of explanation and understanding only.

In the drawings:

Fig. 1 is a sectional view as taken perpendicular to an axis of rotation of a fuel injection pump according to the invention;

Fig. 2 is a sectional view as taken along the axis of rotation of the fuel injection pump as illustrated in Fig. 1;

Figs. 3(a), 3(b), 3(c), 3(d), 3(e), 3(f), 3(g), and 3(h) are partially sectional views which show time-sequential operations of plungers and a cam ring;

Figs. 4(a), 4(b), 4(c), and 4(d) are partially sectional views which shows time-sequential operations of a safeguard when a contact surface between a plunger and a cam ring is baked; and

Fig. 5 is a partially sectional view which shows a rotation-to-linear motion transforming mechanism used in a conventional fuel injection pump for automotive engines.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, wherein like reference numbers refer to like parts in several views, particularly to Figs. 1 and 2, there is shown a fuel injection pump 1 according to the invention which is designed to compress and deliver high-pressure fuel to a common rail of a diesel engine (not shown).

The fuel injection pump 1 consists essentially of a feed pump 2, a regulator valve 3, a fuel regulator valve 4 made of a solenoid control valve (SCV), and a high-pressure pump 5. The feed pump 2 is illustrated in Fig. 2 as being developed through 90° .

The fuel injection pump 1 has a housing assembly made up of a body 6, a cover 7, and a cylinder head 8. The body 6 and the cover 7 are each made of aluminum. The cylinder head 8 is made of iron.

The feed pump 2 is implemented by a trochoid pump and driven by a cam shaft 11 to suck the fuel from a fuel inlet 10 and supply it to the high-pressure pump 5 through the fuel regulator valve 4. The cam shaft 11 is driven by a crankshaft of the engine.

The regulator valve 3 is disposed in a fuel path

communicating between an outlet and an inlet of the feed pump 2. When the pressure of the fuel at the outlet of the feed pump 2 exceeds a given allowable level, the regulator valve 3 is opened to keep the discharge pressure thereof below the allowable level.

The fuel regulator valve 4 is equipped with a coil which is energized by an ECU (engine control unit not shown) to control the amount of fuel to be supplied to the high-pressure pump 5, thereby controlling the pressure of fuel within the common rail.

The high-pressure pump 5 works to pressurize the fuel supplied from the fuel regulator valve 4 and feed it to the common rail. The high-pressure pump 5 is made up of a rotation-to-linear motion transforming mechanism 13, two plunger pumps 14, suction valves 16, and a discharge valve 17. The rotation-to-linear motion transforming mechanism 13 works to transform torque transmitted from the engine into reciprocating motion of the plungers 12. Each of the plunger pumps 14 has a pressurizing chamber 15 into which the fuel is sucked by the motion of the plunger 12 from the suction valve 16. The discharge valve 17 works to deliver the fuel pressurized in the pressurizing chambers 15 to the common rail. Only either one of the plunger pumps 14 may be installed in the high-pressure pump 5.

The rotation-to-linear motion transforming mechanism 13 is installed within a cam chamber 18 formed in the housing assembly. The rotation-to-linear motion transforming mechanism 13 consists of an eccentric cam 19, a cam ring 21, and the plungers 12. The cam ring 21 is fitted around the eccentric cam 19. The plungers 12

are pressed against the cam ring 21 so that they reciprocate following movement of the cam ring 21.

The cam chamber 18 is filled with the fuel supplied through a fuel path 22 from the feed pump 2. The fuel path 22 has formed therein an orifice 22a. An excess of the fuel within the cam chamber 18 is discharged from a fuel outlet 23 and returned back to the fuel pump (not shown).

The eccentric cam 19 is made of a cylindrical member which is joined to or formed integrally with the cam shaft 11 driven by the output torque of the engine. Rotation of the cam shaft 11 causes the eccentric cam 19 to rotate eccentrically with respect to the axis of rotation of the cam shaft 11.

The cam ring 21 is, as clearly shown in Fig. 2, installed to be slidable on the eccentric cam 19 through a hollow cylindrical plain bearing (bush) 24. The cam ring 21 has formed therein a through hole 21a within which the eccentric cam 19 and the plain bearing 24 are disposed.

The cam ring 21 has formed on the periphery thereof flat surfaces 21b on which the plungers 12 abut slidably. The two plungers 12 are opposed to each other in alignment across the cam ring 21. Two of the flat surfaces 21b on which the plungers 12 abut are opposed to each other.

Each of the plungers 12 has a disc or tappet 12a formed integrally on an end thereof. The tappet 12a has a flat end surface 12b (will also be referred to as a plunger surface below) which is in slidable abutment with the flat surface 21b of the cam ring 21.

Disposed between each of the tappets 12a and the cylinder head 8 is a coil spring 25 which works to urge the plunger surface 12b into constant abutment with one of the flat surfaces 21b of the cam ring 21. The sum of the spring pressure of the springs 25 and the fuel pressure acting on the plungers 12 works to hold the cam ring 21 from turning and urge the cam ring 21 to move eccentrically with the flat surfaces 21b oriented in the same directions, thereby reciprocating the plungers 12 cyclically.

Each of the plungers 12 is slidably retained within a cylindrical chamber 8a (will also be referred to as a cylinder below) formed in the cylinder head 8. The plungers 12 are, as described above, reciprocated by the cam ring 21 to increase or decrease the volume of the pressurizing chambers 15 cyclically.

Specifically, when each of the plungers 12 moves downward (i.e., toward the center of rotation of the eccentric cam 19), it will cause a corresponding one of the pressurizing chambers 15 to be increased in volume, thus resulting in a drop in pressure within the pressurizing chamber 15. This pressure drop causes the discharge valve 17 to be closed and the suction valve 16 to be opened, thereby sucking into the pressurizing chamber 15 the fuel which has been pressurized by the feed pump 2 and regulated in amount by the fuel regulator valve 4.

Conversely, when each of the plungers 12 moves upward (i.e., away from the center of rotation of the eccentric cam 19), it will cause a corresponding one of the pressurizing chambers 15 to be decreased in volume, thus resulting in a rise in pressure within the

pressurizing chamber 15. This pressure rise causes the suction valve 16 to be closed. When the pressure within the pressurizing chamber 15 reaches a given upper limit, it causes the discharge valve 17 to be opened to expel the pressurized fuel from the pressurizing chamber 15 to the common rail.

The operation of the rotation-to-linear motion transforming mechanism 13 will be described below with reference to Figs. 3(a) to 3(h). In the following discussion, the downward movement of each of the plungers 12 toward the center of rotation of the eccentric cam 19 to suck the fuel into the pressurizing chambers 15 will be referred to as a suction stroke, while the upward movement of each of the plungers 12 toward the suction valves 16 to pressurize the fuel in the pressurizing chambers 15 will be referred to as a compression stroke.

The plungers 12 are, as described above, opposed diametrically to each other across the cam ring 21, so that they are moved in 180° out of phase with each other. In other words, when one of the plungers 12 is experiencing the suction stroke, the other is experiencing the compression stroke.

When the center of rotation of the eccentric cam 19 is, as illustrated in Fig. 3(a), located just below that of the cam shaft 11, an upper one of the plungers 12 is placed in the bottom dead center position, while the lower plunger 12 is placed in the top dead center. The angular position of the eccentric cam 19 in this condition will be defined below as zero (0) degree.

A counterclockwise rotation of the cam shaft 11, as viewed in

the drawings, from 0° will cause the eccentric cam 19 and the cam ring 21 to rotate eccentrically with respect to the cams shaft 11. This causes the upper plunger 12 abutting an upper one of the flat surfaces 21b of the cam ring 21 to move from the bottom dead center position to the top dead center position within the cylinder chamber 8a. Specifically, when the angular position θ of the cam shaft 11 lies within a range of 0° and 180° (i.e., $0° < \theta < 180°$), the upper plunger 12 is in the compression stroke.

The lower plunger 12 is placed in the suction stroke when the angular position θ of the cam shaft 11 lies within a range of 0° and 180° (i.e., $0° < \theta < 180°$). Specifically, the lower plunger 12 moves from the top dead center position to the bottom dead center position within the cylinder chamber 8a between 0° and 180°.

During the compression stroke of the upper plunger 12, a greater pressure oriented toward the cam ring 21 that is the sum of the spring pressure produced by an upper one of the springs 25 and the fuel pressure in an upper one of the pressurizing chambers 15 acts on the upper plunger 12. On the other hand, the lower plunger 12 experiencing the suction stroke is urged by the spring pressure produced by the lower spring 25 toward the cam ring 21.

Specifically, the pressure urging one of the plungers 12 experiencing the compression stroke toward the cam ring 21 is greater than that urging the other plunger 12 experiencing the suction stroke toward the cam ring 21.

The flat surfaces 21b of the cam ring 21 are in unparallel to each other. The plungers 12 have longitudinal center lines

extending parallel to each other (or in alignment with each other). In other words, travel paths of the plungers 12 extend parallel to each other. Therefore, when the pressure acting on one of the plungers 12 is greater than that acting on the other one, one of the flat surface 21b of the cam ring 21 on which the greater of the pressures acts is urged into surface-to-surface contact with a corresponding one of the plunger surfaces 12b of the plungers 12.

Specifically, when the upper plunger 12 is placed in the compression stroke, the upper plunger surface 12b abuts the upper flat surface 21b of the cam ring 21, while the lower plunger surface 12b is inclined at a given angle to the lower flat surface 21b of the cam ring 21, thereby creasing a gap therebetween into which the fuel in the cam chamber 18 flows.

When the angular position θ of the cam shaft 11 reaches, as shown in Fig. 3(e), 180°, the upper plunger 12 reaches the top dead center position, while the lower plunger 12 reaches the bottom dead center position. The upper plunger 12, thus, completes the compression stroke, while the lower plunger 12 completes the suction stroke.

When the angular position θ of the cam shaft 11 exceeds 180°, as contrasted with when the angular position θ of the cam shaft 11 lies within a range of 0° and 180°, the upper plunger 12 starts the suction stroke, while the lower plunger 12 starts the compression stroke. The plunger surface 12b of a lower one of the plungers 12 experiencing the compression stroke, thus, abuts the lower flat surface 21b of the cam ring 21, while the upper plunger

surface 12b is inclined at a given angle to the upper flat surface 21b of the cam ring 21, thereby creasing a gap therebetween into which the fuel in the cam chamber 18 flows.

When the angular position θ of the cam shaft 11 reaches 360° , the plungers 12 are returned to the initial positions, respectively.

As is apparent from the above discussion, one of the plungers 12 that is experiencing the suction stroke has the surface 12b thereof inclined to the flat surface 21b of the cam ring 21 to create the gap therebetween into which the fuel within the cam chamber 18 flows for lubrication. However, when the water enters between the flat surface 21b of the cam ring 21 and the plunger surface 12b for some reason, it will result in a lack of lubrication therebetween, which may lead to baking of a contact surface between the flat surface 21b and the plunger surface 12b. The eccentric cam 19 revolving the cam ring 21 eccentrically is, as described above, driven by the output of the engine. The baking of the contact surface, thus, causes a greater toque outputted from the engine to be transmitted through the contact surface to the plungers 12, which results in breakage of the plungers 12. The breakage may further cause fragmentations of the plungers 12 to be forced into a gap between the cam ring 21 and the housing body 6 surrounding the cam ring 21, which results in breakage of the housing body 6.

In order to avoid the above problem, the cam ring 21 is, as shown in Fig. 1, equipped with safeguards 26 which are responsive to input of a given degree of torque to the cam ring 21 to break the

cam ring 21 mechanically. The safeguards 26 are preferably designed to break the cam ring 21 upon input of torque which is somewhat greater in degree than a maximum torque acting on the cam ring 21 when the fuel injection pump 1 is operating normally and at least smaller than a failure strength of the housing body 6 surrounding the cam ring 21.

The safeguards 26 are implemented by structural portions of the cam ring 21 which have a mechanical strength weak enough to create cracks in the cam ring 21 when an excessive torque is applied to the cam ring 21. Specifically, the safeguards 26 are each made of a *V*-groove formed in an outer wall of the cam ring 21. Each of the *V*-grooves may extend from one end to the other end of the cam ring 21 in an axial direction of the cam ring 21 or alternatively be formed only in a portion of the outer wall of the cam ring 21.

The safeguards 26 are formed in diametrically opposed side surfaces of the cam ring 21 which do not abut the plungers surfaces 12b and at locations on which a greater tensile stress acts when the resistance to sliding motion of the cam ring 21 and the plungers 12 undesirably increases, for example, when the contact surfaces between the cam ring 21 and the plungers 12 are baked.

Only the one safeguard 26 may be formed in the cam ring 21. The two safeguards 26 are preferably used in order to ensure the breakage of the cam ring 21 if either of the plungers 12 is seized.

The operation of the safeguards 26 when the contact surfaces between the flat surfaces 21b of the cam ring 21 and the plunger surfaces 12b of the plungers 12 are baked will be described below in

detail with reference to Figs. 4(a) to (d).

As described already, during the suction stroke of each of the plungers 12, a gap is created between the flat surface 21b of the cam ring 21 and the plunger surface 12b into which the fuel enters. When the water enters the gap for some reason, and the plunger 12 starts the compression stroke, it will result in a lack of lubrication on the contact surface between the flat surface 21b and the plunger surface 12b, thus causing the contact surface to be baked.

The eccentric cam 19 is driven by the output of the engine, so that it continues to rotate even when the contact surface, as indicated by *A* in Fig. 4(b), between the flat surface 21b of the cam ring 21 and the plunger surface 12b is baked during the compression stroke of the plunger 12. This results in addition of a tensile stress greater than usual to a portion of the cam ring 21, as indicated by *B* in Fig. 4(b), which also results in addition of a compressive stress greater than usual to a portion of the cam ring 21, as indicated by *C*.

The addition of the tensile stress to the portion of the cam ring 21, as indicated by *B*, causes a corresponding one of the safeguards 26 to be split to create a crack in the portion *B* of the cam ring 21. The crack causes the portion *B* to expand vertically, as viewed in Fig. 4(c), thus resulting in an increased inner diameter of the cam ring 21. This causes the eccentric cam 19 to idle within the cam ring 21, thus resulting in interruption of transmission of torque of the eccentric cam 19 to the cam ring 21, which avoids addition of an excessive load to the plungers 12.

If the plungers 12 are broken, as described above, it may cause fragmentations thereof to be forced into the gap between the cam ring 21 and the housing body 6 which results in breakage of the housing body 6 and leakage of the fuel outside the housing body 6. The safeguards 26 work to avoid this problem, thus eliminating the need for increasing a clearance between the cam ring 21 and the housing body 6, that is, increasing the size of the fuel injection pump 1.

Each of the safeguards 26 is provided in a portion of the cam ring 21 on which a great tensile stress acts. Thus, if a plunger thrust resistance is developed on the contact surface between the cam ring 21 and each of the plungers 12, the safeguards 26 are responsive to a physical load on the cam ring 12 in a direction of rotation thereof to undergo breakage and thus work to minimize the damage to parts other than the cam ring 21.

Each of the safeguards 26 may alternatively be made of a dent or a groove that is different in shape from *V*. For example, the safeguards 26 may be made of a *U*- or *C*-shaped groove. Further, the safeguards 26 may alternatively be formed only in an inner peripheral wall of the cam ring 21 or both in the outer and inner peripheral walls of the cam ring 21.

Each of the safeguards 26 may alternatively be implemented by decreasing the thickness between the outer and inner peripheral surfaces of the cam ring 21 to form thick walls. The thick wall may extend from one end to the other of the cam ring 21 in the axial direction of the cam ring 21 or alternatively be formed intermediate

between the ends of the cam ring 21.

Each the safeguards 26 may alternatively be implemented by one or some holes extending through the outer and inner peripheral surfaces of the cam ring 21.

Each of the safeguards 26 may alternatively be located in a portion of the cam ring 21 which is responsive to a compressive stress to create a crack in the cam ring 21. Specifically, the safeguards 26 are preferably designed to be broken upon application of a physical load in a direction of rotation of the cam ring 21.

The safeguards 26 are, as described above, provided in the rotation-to-linear motion transforming mechanism 13, but may be used in any other type of rotation-to-linear motion transforming mechanism equipped with a cam ring and a plunger.

While the present invention has been disclosed in terms of the preferred embodiments in order to facilitate better understanding thereof, it should be appreciated that the invention can be embodied in various ways without departing from the principle of the invention. Therefore, the invention should be understood to include all possible embodiments and modifications to the shown embodiments which can be embodied without departing from the principle of the invention as set forth in the appended claims.